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Valuing high technology growth firms

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Abstract

For the valuation of fast growing innovative firms Schwartz and Moon (2000, 2001) develop a fundamentals based valuation model where key parameters, such as revenues and expenses, follow stochastic processes. Guided by economic theory, this paper tests this model on a sample of around 30,000 technology firm quarter observations from 1992 to 2009 using realized accounting data and benchmark it against the traditional Enterprise Value-Sales Multiple. Our results show that the Schwartz-Moon model is on average nearly as accurate as the multiple approach, while it is even more accurate in certain industries such as pharmaceutical and computer firms. Most importantly, the Schwartz-Moon model shows the ability to indicate severe market over- or undervaluation.

JEL classification: G11, G12, G17, G33

Keywords: Schwartz-Moon model, market mispricing, empirical test, company valuation

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1. Introduction

Web based social networks like facebook, twitter and co. are currently one of the fastest growing industries and therefore attracting investors' attention. Earlier this year, Goldman Sachs bought a share of facebook implicitly valuing this company at around \$50 billion. The result was a market capitalization comparable to mature internet firms as Ebay or Amazon.¹ More recently, the deal-of-the-day websites Groupon and LivingSocial announced plans for their IPOs corresponding to firm values of \$30 billion and \$15 billion, respectively.² Hence, the challenging exercise of valuing fast growing technology firms is becoming popular again despite the recent financial crisis.

In response to the demand for a valuation model suitable for such firms Schwartz and Moon (2000) and Schwartz and Moon (2001) develop and extend a model explicitly focusing on the value generating process in high technology growth stocks. It is based on fundamental assumptions about the expected growth rate of revenues and the company's cost structure to derive a value for the technology firms. Using simple Monte Carlo techniques and short term historical accounting data, the Schwartz-Moon model simulates a growing technology firm's possible paths of development. Then, it calculates a fundamental firm value by averaging all discounted, risk-adjusted outcomes of the simulated enterprise values. Additionally, throughout the growth process firms may default. Therefore, the model provides investors not only with a value estimate but also with a long term probability of bankruptcy, which is not the case for the standard valuation procedures such as multiples. Finally, given that these firms often experience losses and do not have analyst coverage, one needs to recall, that the most accurate valuation methods, e.g., Discounted Cash Flow models or price earnings multiples, are not applicable.

¹ Wall Street Journal (01/06/11): Goldman Flooded with Facebook Orders.

² Wall Street Journal (07/08/11): IPO Traffic Jam? Groupon vs. Living Social.

Based on these thoughts, the issue arises whether the Schwartz-Moon model can fill this gap in the valuation literature, despite the difficulty that many of the model's input parameters need to be estimated ex-ante. Being precise, we ask the following three research questions:

First, given the theoretical advantages but challenging input parameter estimation of the Schwartz-Moon model, how does an economic reasonable, but at the same time feasible implementation look like? Second, how does the proposed model implementation perform in terms of valuation accuracy? Third, considering that the model uses fundamental accounting information as an anchor, is it possible to indicate market mispricing?

Answering these questions yields the following key results: First, building on economic theory regarding the development of key accounting and cash flow figures in a competitive market environment, we present an easily applicable configuration of the Schwartz-Moon model for large scale valuation purposes on a sample of around 30,000 technology firm quarter observations from 1992 to 2009 using realized accounting data. Second, the fundamentals based Schwartz-Moon model performs *on average* nearly as good as the market-mood capturing Enterprise-Value-Sales method with regard to deviations from market values. However, there are clearly smaller valuation errors for firms in the pharmaceutical and computer industries and for smaller companies. Note, that this perspective assumes that markets are on average efficient considering the complete time period. Finally, leaving this efficiency perspective and turning to the last question of potential mispricing in each quarter from 1992 until 2009 the Schwartz-Moon model shows the ability to indicate severe over- or undervaluation by the markets and to produce reasonable estimates for the probability of default.

By providing and testing an applicable implementation of the Schwartz-Moon model we contribute to the literature in the following ways: First, our findings add to the research on company

valuation by offering promising results how to accurately value small firms, which often exhibit losses and are therefore excluded in other studies.³ Furthermore, as the model only relies on a short history of two years of firm-specific accounting data it is also applicable to non-publicly traded firms. Thus, it might be of special interest for investors who target so far unlisted firms and in particular for venture capital and private equity investors like pooled development funds who invest in small to medium technology enterprises as documented in Cumming, Fleming and Suchard (2005). Regarding the above outlined results on model accuracy obtained from averaging all outcomes over the complete time span from 1992 until 2009, we believe that our findings are conservative, because our benchmark regarding the model's accuracy are firm value predictions obtained from Enterprise-Value-Sales multiples (EV-Sales). This results in a rather unfair comparison because observed valuations are highly influenced by market sentiment as shown in Inderst and Müller (2004). Put differently, while the Schwartz-Moon model is purely based on historical accounting data, multiples are generally calibrated to capture the current market mood by explicitly relying on the market values of competitor firms. At the same time this characteristic allows the fundamentals based Schwartz-Moon model to detect periods of severe market mispricing. Thus, we add to the literature which indicates that the financial accounting data can serve as an anchor for rational pricing during these times as in Bhattacharya, Demers and Joos (2010). This is especially true for technology growth firms whose valuations are highly subjective and therefore strongly affected by investor sentiment as documented in Baker and Wurgler (2006).

The remainder of this paper is structured as follows. In section 2 we discuss the properties of

³ In fact, taking a closer look at recent valuation model accuracy studies such as Liu, Nissim and Thomas (2002), Bhojraj and Lee (2002) or Eberhart (2001), most of them exclude all firms that do not fulfill criteria such as positive earnings, analyst coverage, share price larger than \$3 and minimum sales of \$100 million.

technology growth firms in the context of firm valuation. Section 3 gives a reminder of the Schwartz-Moon model and introduces the benchmark valuation procedure. Section 4 describes the sample and model implementation issues. In section 5 we investigate the model's accuracy based on the results of our empirical analyses while section 6 presents the robustness checks. Finally, section 7 concludes.

2. Related literature: Firm growth and valuation

In this section we briefly put the Schwartz-Moon model in the historical context and present its roots in the overall valuation literature. To start with the “nifty fifty”, they were the high-flying growth stocks of the 1960ties and early seventies. Those companies, such as General Electric, IBM, Texas Instruments and Xerox were the growth firms of their time as documented in Siegel (2002). Due to their notably high valuations, those firms were later compared to new economy stocks enjoying tremendous high valuations in the late 1990ties as stated in Baker and Wurgler (2006). Still, while the “nifty fifty“ were strongly growing companies, their valuation was based on the ability to generate rapid and sustained earnings growth and persistently increase their dividends. In addition, those firms were already well established large cap entities, thereby confirming Gibrat's rule and the theoretical models of Simon and Bonini (1958) and Lucas Jr. (1967) that assume growth to be independent from firm size. Consequently, growing firms could easily be valued using standard valuation methods such as the discounted cash flow model with analyst forecast data or the Price-Earnings-Ratio with a sufficient peer group.

The tremendous rise in high technology stock prices during the end of the 1990ties and its subsequent fall throughout the early years in the new century let the economics of technology firms gain significant attention again. Practitioners and researchers started to realize that internet

stocks are a chaotic mishmash defying any rules of valuation.⁴ So they began to question the relation between financial ratios and equity value of stocks as documented by Core, Guay and Buskirk (2003) and proposed new measures of technology firm value drivers such as customer's internet usage as in Trueman, Wong and Zhang (2000). In a more general approach, Zingales (2000) describes the appearance of a new type of firm based on new technology. He finds three factors to disturb existing firm theories: Reduced value generation by physical assets, increased competition and the importance of human assets. But why would new technology have influence on firm valuation approaches? McGrath (1997) relates investments in high technology firms with real options logic. In her framework, the value of the technology option is the cost to develop the technology. Completing the development of the technology will create an asset which is the underlying right of the firm to extract rents from the technology. This gives three insights.

First, growing technology firms might inhibit losses as they face costs of development, but no yet marketable products. In this context, Demers and Lev (2001) argue that high technology firms require significant up-front capital to establish their technological architecture. As a result, Bartov, Mohanram and Seethamraju (2002) find that since the 1990ties, innovative high technology firms are expected to grow rapidly, while they are still not profitable. In this study we will present a sample of 29,477 technology firm quarter observations with median annual sales of 142 \$m and a significant share (34%) of negative earnings observations. Consequently, we conclude that recent studies on valuation model accuracy do not include a significant share of high technology companies. This leaves both the natural valuation model for fundamental pricing, the DCF and the most accurate valuation model, the Price-Earnings-Multiple approach less applicable.

⁴ Wall Street Journal (12/27/11): Analyst Discovers the Order in Internet Stocks Valuation.

Second, from a stock market perspective high technology growth firms have specific characteristics. Their stocks are exposed to the severe volatility as documented in Ofek and Richardson (2003), which makes it difficult to determine the underlying value. At the same time there is a strong influence of investor sentiment onto the value of technology firms found in Baker and Wurgler (2006) or Inderst and Mueller (2004). Hence, relative valuation methods, i.e., multiples, for high technology firms are heavily influenced by the current mood of the market. Compared to fundamentally based valuation models as DCF, the multiples should not be able to make any statements about overall market over- or undervaluation. Consequently, valuation methods based on financial statement data should therefore have the potential to serve as rationale benchmark during volatile and speculative market periods. This is especially important as prices reflect fundamentals in the long run as presented in Coakley and Fuertes (2006).

Thirdly, the risk of the new technology failing can result in bankruptcy. Thus, the risk of default plays an important role in valuation, which is especially true for this type of firms. Vassalou and Xing (2004), e.g., report default risk to be a relevant factor for explaining equity returns. Beside the general fact that bankruptcy is costly and negatively affects small and large investors, information on default risk is especially important for under-diversified investors. Cumming and MacIntosh (2003) document tremendous default risks with failure rates of 30% for portfolios that are specialized to young entrepreneurial firms. These results show that valuation models -especially with regard to small companies- should incorporate default risk explicitly. Since this is the case in the Schwartz-Moon framework, this model should be preferable to standard approaches, which are typically working on a going concern basis.

In sum, we see that standard valuation procedures are less applicable for high technology firms, which are especially influenced by market mood and exposed to default risk. Moreover,

Hand (2005) and Armstrong, Davila and Foster (2006) find that traditional accounting measures such as balance sheet, income statement and cash-flow data are able to explain variation in market values for growing technology firms. Taking these specifics into account the Schwartz-Moon model might offer a possibility to determine a fundamentally justified value of high technology growth firms. In the following we present the original model.

3. Valuation models

3.1. Fundamental pricing: The Schwartz-Moon model

The Schwartz-Moon model (2000, 2001) is most easily explained in the context of traditional valuation models, such as the familiar discounted cash flow model, where the cash flow to equity (FTE) is discounted at an appropriate risk adjusted cost of equity as in Francis, Olsson and Oswald (2000). For all these models, one of the most challenging tasks is the derivation of future payoffs. While there are several ways to tackle this problem, the most sensible method is to forecast future balance sheets and income statements and derive the necessary payoff-figures as in Lundholm and O'Keefe (2001). Following this logic, one needs at least forecasts of the basic financial statements items as shown in the next two figures.

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-----Please insert Figure 2 approximately here-----

Since analysts' forecasts for high technology firms are often not available, the commonly applied forecasting technique is the percentage of sales method. Here, one explicitly focuses on revenues

forecasts and the other value relevant parameters are tied to these forecasts based on a historical ratio analysis as applied in Nissim and Penman (2001). The revenues forecasts are influenced by many parameters, such as industry dynamics, actions from competitors (amongst others). Consequently, after some finite forecast horizon, it is reasonably assumed that initially high growth rates of revenues will converge to average industry levels. Finally, the company will achieve a mature, steady-state status and revenues grow with the industry. The convergence to industry levels is theoretically well established as in Denrell (2004) and commonly applied in empirical studies concerned with company valuation such as Lee, Myers and Swaminathan (1999).

The Schwartz-Moon model is exactly based on these thoughts, since it models the value driving input parameters given by the income statement and the balance sheet with stochastic processes. Below we present the model as introduced by Schwartz and Moon (2001).

Following the percentage of sales method, revenue dynamics (R) are given by the stochastic differential equation:

$$\frac{dR(t)}{R(t)} = [\mu(t) - \lambda_R \cdot \sigma(t)]dt + \sigma(t) \cdot dz_R(t) \quad (1)$$

where the drift term $\mu(t)$ represents the expected growth rate in revenues and $\sigma(t)$ is the growth rates' volatility. Unanticipated changes in growth rates are modeled by the random variable z_R , following a Wiener process. The risk adjustment term λ_R accounts for the uncertainty and allows for discounting at the risk free rate later. With time t , the initial growth rates do converge to their long term growth rate $\bar{\mu}$ following a simple Ornstein-Uhlenbeck process.

$$d\mu(t) = [\kappa_\mu(\bar{\mu} - \mu(t)) - \lambda_\mu \cdot \eta(t)]dt + \eta(t) \cdot dz_\mu(t) \quad (2)$$

where κ_μ denotes the speed of convergence and $\eta(t)$ is the volatility of the sales growth rate. Different from Schwartz and Moon (2001) we do not make the simplifying assumption that the

true and the risk adjusted revenues growth processes are the same which is why we introduce the risk adjustment term λ_μ . Unanticipated changes in revenues $\sigma(t)$ converge with κ_σ to their long-term average $\bar{\sigma}$, while the volatility of expected growth $\eta(t)$ converges to zero.

$$d\sigma(t) = \kappa_\sigma \cdot [\bar{\sigma} - \sigma(t)] dt \quad (3)$$

$$d\eta(t) = -\kappa_\eta \cdot \eta(t) dt \quad (4)$$

Summing up, the two main parameters of the revenue process (growth rate $\mu(t)$ and the growth rates' volatility $\sigma(t)$) exhibit the desirably property of long term convergence justified by a competitive market environment.

Turning to the second item on the income statement, cost dynamics $C(t)$ are modeled based on two components. The first component is variable cost dynamics $\gamma(t)$, which is proportional to the firm's revenues. The second component is fixed costs F .

$$C(t) = \gamma(t) \cdot R(t) + F \quad (5)$$

Again, cost dynamics are assumed to converge to their industry levels according to the following mean-reverting process:

$$d\gamma(t) = [\kappa_\gamma (\bar{\gamma} - \gamma(t)) - \lambda_\gamma \cdot \varphi(t)] dt + \varphi(t) \cdot dz_\gamma(t) \quad (6)$$

where κ_γ denotes the speed of convergence at which variable costs $\gamma(t)$ converge to their long term average $\bar{\gamma}$. Here we also adjust for the uncertainty by adding the risk adjustment term λ_γ . Unanticipated changes in variable costs are modeled by $\varphi(t)$, converging deterministically with κ_φ against long term variable cost volatility $\bar{\varphi}$.

$$d\varphi(t) = \kappa_\varphi \cdot [\bar{\varphi} - \varphi(t)] dt \quad (7)$$

As Schwartz and Moon (2001) suggest it is reasonable to assume the three speed of adjustment coefficients to be the same, leaving us with one single κ . Dividing $\log(2)$ by κ yields the half-life of the processes, which can easily be interpreted.⁵ While revenues and costs are modeled independently from the balance sheet, the development of property, plant and equipment $PPE(t)$ depends on the development of capital expenditures $CE(t)$ and depreciation $D(t)$. The former value is assumed to be a fraction cr of revenues while depreciation is assumed to be a fraction dp of the accumulated property, plant and equipment. Consequently, both financial statements are linked consistently to each other by:

$$dPPE(t) = [-D(t) + CE(t)]dt \quad (8)$$

Finally, taxes and the dynamics of loss carry forwards are considered by Schwartz and Moon (2001). Since firms can offset initially negative earnings with future positive earnings, we calculate loss carry forward dynamics as:

$$dL(t) = \begin{cases} -[Y(t) + Tax(t)]dt, & \text{if } L(t) > [Y(t) + Tax(t)]dt \\ -\max[L(t)dt, 0], & \text{else} \end{cases} \quad (9)$$

Controlling for tax payments $Tax(t)$ and loss carry forwards $L(t)$, the after tax income $Y(t)$ in the Schwartz-Moon model is given by:

$$Y(t) = R(t) - C(t) - D(t) - Tax(t) \quad (10)$$

Assuming that no dividends are paid and positive cash-flows are reinvested, earning the risk-free rate of interest r , the amount of cash available to the firm X evolves according to:

$$dX(t) = [r \cdot X(t) + Y(t) + D(t) - CE(t)]dt \quad (11)$$

⁵ Assuming exponential decay, the half-life can be derived by solving the following equation for t_h : $e^{-\kappa t_h} = \frac{1}{2}$.

Firms fail when their available cash falls below a certain threshold X^* and the enterprise value is set to zero. Otherwise the model implied fundamental value at time t is calculated by discounting the expected value of the firm at time T under the risk neutral probability measure Π with the risk free rate r as the three stochastic processes are corrected for uncertainty by the risk premiums λ_R , λ_μ and λ_γ . The firm's enterprise value consists of two components. The cash amount outstanding and second the residual company value, which is calculated as $EBITDA = R(T) - C(T)$ times a multiple M .

$$\widehat{EV(0)} = E^\Pi \{X(T) + M \cdot [R(T) - C(T)]\} \cdot e^{-r \cdot T} \quad (12)$$

The assumptions of no dividend pay-out, no explicit modeling of tax-shields due to the deductibility of interest payments and the solution of the terminal value problem via an exit multiple deserves discussion. While it seems restrictive at first glance, the model is basically employed in a Modigliani and Miller (1958) framework, since it is assumed that it does not matter whether equity-owners or the firm holds cash. Furthermore, within the branch of literature concerned with capital structure choice, such as Miller (1977) and Ross (1985) amongst others, one might argue that advantages and disadvantages of debt financing might balance, so it might be a simplifying but justifiable assumption, that the financing decision is not considered explicitly in the Schwartz-Moon model.

Concerning the terminal value problem, it should be noted, that the finite forecast horizon is chosen to be 25 years as in Schwartz and Moon (2001). Consequently, the calculated terminal value plays only a minor role as shown in the robustness section.

3.2. Introducing a benchmark: Enterprise-Value-Sales-Multiple

The Schwartz-Moon model is based on fundamental valuation. Therefore, the natural benchmark would be the DCF model. As argued earlier, the firms in our sample often lack analyst coverage and hence do not provide the input parameters for the DCF model. Alternatively, we look at relative financial ratios referred to as multiples.

Multiples are widely used in practice by consultants, analysts and investment bankers as shown for example by Bhojraj and Lee (2002). Among other traditional valuation methods (DCF, residual income model) they generally produce the smallest valuation errors as shown by Liu, Nissim and Thomas (2002) and Bhojraj and Lee (2002). Thus, we choose to benchmark the Schwartz-Moon model against this very accurate valuation method. As noted beforehand, there are many multiples available (Price-Earnings, Price-Book, Price-Sales etc.) and these can be implemented in many different ways (simple peer-group comparison vs. sophisticated regression approach). Consequently, we have to choose among these many possibilities. Given the fact, that our study is concerned with technology growth firms, many of them have negative earnings or even negative EBITDA. Hence, standard multiples such as Price-Earnings or EBITDA-Sales are not applicable. At the same time we look for a comparable measure which comes close to the idea of the Schwartz-Moon model with the major driving force being sales from its stochastic processes. Considering sales as the flow item from the income statement our choice is naturally guided to the Enterprise-Value-Sales Multiple.

The Enterprise-Value-Sales method evaluated in this paper follows Alford (1992), where a firm i 's value is estimated by the product of firm i 's sales at τ and the median of the j peer group's (PG) EV-Sales multiples.

$$\widehat{EV(t)}_i = Sales(\tau)_i \cdot median_{j \in PG_i} \left\{ \frac{EV(t)_j}{Sales(\tau)_j} \right\} \quad (13)$$

where enterprise value (EV) is the market value of equity plus the book value of debt. Note that \widehat{EV} is the estimated value whereas EV simply denotes observable information. A key component in relative pricing is the identification of comparable companies. Alford (1992) examines the effects of comparable company selection on relative valuation accuracy and finds that comparable companies selected on industry classification and additional measure such as profitability yield the lowest estimation errors. Therefore, we perform EV-Sales Multiple valuations based on four digit SIC code industry classifications. Within the industry we group firms by their return on assets (RNOA) to account for profitability effects (cf. appendix 1). That is we choose those six firms that are closest to firm i 's RNOA within the preceding year. If fewer than six companies are available in this SIC code classification, we relax this requirement to companies with the same three, two and one digit SIC code. The peer group median then is calculated to obtain the multiple. The product of the multiple and the firm's sales yields the estimated enterprise value.

4. Data and methodology

4.1. Data collection

To construct our sample of high technology firms, we merge the CRSP database for market data with Compustat North America quarterly and yearly accounting data beginning in 1970. We consider all firms that fall under the Bhojraj and Lee (2002) high technology industry SIC code definition beginning in 1992 until 2009.⁶ That is biotechnology (SIC codes 2833-2836 and 8731-8734), computer (3570-3577 and 7371-7379), electronics (3600-3674) and telecommunication (4810-4841). We add SIC code 7370 (Computer Programming, Data Process) in order to keep firms such as Google or Lycos in our sample. We exclude all firm observations with negative

⁶ We start at the first quarter 1992 since we need eight quarters of accounting information from 1990.

sales, variable costs, capital expenditure and negative enterprise values. This leaves us with 2,262 individual firms covering 29,477 quarters in total as can be found in Table 1 in the appendix.

4.2. Model implementation

The most challenging issue in applying the Schwartz-Moon model is parameter estimation as noted in Schwartz and Moon (2000). Unlike an investment banker who has detailed information about the firm's development, recent m&a activity and strategy decisions we are valuing a rather anonymous sample of around 30,000 firm quarters. Additionally, forward looking information as analyst's sales and earnings forecast's cannot be applied due to limited coverage of high technology firms. This is especially an issue for private technology firms which present an important interest group for venture capital and private equity investors or pre-IPO firms that may also be of interest for other institutional and private investors like pooled development funds who invest in small to medium technology enterprises as documented in Cumming, Fleming and Suchard (2005). Therefore, our analysis is primarily based on short term historical accounting information, which is the only information set left for these firms.

The Schwartz-Moon model includes 22 different input parameters. While most parameters are estimated on a firm level basis especially the long term parameters are determined on industry levels (i.e., three digit SIC codes). Including information from comparable firms from the same industry decreases the volatility of estimated firm values as shown in Eberhart (2001) and hence yields better estimates. From the point of importance the 22 parameters can be divided into critical and uncritical parameters. The critical parameters with a larger impact on the simulation results come from the revenue and the cost processes because these two processes are the main

drivers for a firm's EBIT. The estimation of the seven critical parameters is presented in the next two paragraphs and their impact is shown in the sensitivity analysis in section 5.

4.2.1. Implementing revenue dynamics

Recall that key input parameters for the firm's revenues are given in equation (1) to (4). Thus, we take the initial sales $R(0)$ as quarterly sales from quarterly accounting statements provided by Compustat for each firm. Initial sales volatility $\sigma(0)$ is calculated using the standard deviation of sales change over the preceding seven quarters and converges to the long term quarterly volatility $\bar{\sigma} = 0.05$ consistent with Schwartz and Moon (2001). Further, they argue that initial expected sales growth $\mu(0)$ should be derived using past income statements and projections of future growth. Many private shareholders or institutional investors targeting small capitalized growth firms will find it difficult to obtain analyst forecasts. In addition, requiring the availability of I/B/E/S forecasts in particular excludes small firms as noted by Liu, Nissim and Thomas (2002). However, to value this type of firms is exactly our aim. Therefore, we do not require any analyst coverage and derive $\mu(0)$ as average sales growth over the prior seven quarterly income statements. While this is notably a weak proxy for future revenues growth it is information commonly available for all technology firms and therefore easy to apply. Additionally, Trueman, Wong and Zhang (2001) show historical revenues growth to have incremental predictive power over analysts' forecasts for internet firms. Long term sales growth $\bar{\mu}$ is set to equal 0.75% percent per quarter, which corresponds to an assumed long term average annual inflation rate of three percent. Initial volatility of expected growth rates in revenues $\eta(0)$ is estimated firm specifically by the standard deviation of the residuals from an AR(1)-regression on the growth rates.

Different from Schwartz and Moon (2001) who set the speed of adjustment coefficients κ exogenously to 0.1, we allow for mean reverting processes with industry specific (two digit SIC) kappas. The rationale behind this approach are common factors which drive the competitive advantage periods within the same industries as analyzed in Waring (1996). Schwartz and Moon (2001) argue that the kappa of the revenues growth rate process has the highest impact. Thus, we calculate the adjustment coefficient κ with the help of revenue dynamics by solving the following equation:

$$\sum_{i=t-5}^{t-8} \frac{saleq_i - saleq_{i-1}}{saleq_{i-1}} = \left(\sum_{i=t-1}^{t-4} \frac{saleq_i - saleq_{i-1}}{saleq_{i-1}} \right) \cdot e^{-4 \cdot \hat{\kappa}} \quad (14)$$

As justified above, the estimated firm specific kappas then are pooled to medians for the same two digit SIC codes. We choose two digit over three digit SIC levels to decrease the large variation in this critical parameter. Still, this estimator generates outliers and yields us a range of estimated kappas corresponding to half-lives from one to 70 quarters. In order to avoid the influence of extreme estimates of the kappas corresponding to unreasonable high half-lives we winsorize these variables at the 1% and 99% percentiles. As the kappas directly influence expected future revenues and costs the speed of adjustment parameters are crucial for the three stochastic processes.

4.2.2. *Implementing cost dynamics*

Recall that the input parameters for the cost dynamics are given in equation (5) to (7). Schwartz and Moon (2001) propose to calculate costs using a regression of costs on revenues, where the intercept represents constant fixed costs and the slope is the initial variable costs. On a large

scale application, this leads to cases in which the intercept becomes negative. Those firms would inhibit negative fixed costs, an extremely steep slope and unreasonably high variable costs. Therefore, we deviate from this approach, calculating the variable costs $\gamma(0)$ as the average over the preceding eight quarters of variable costs plus fixed costs divided by revenues. This way we ensure costs to be within reasonable levels. Including fixed costs into this approach assumes that fixed costs grow linearly with firm growth. This might be a weak assumption but seems to be more reasonable than assuming independence from growth. The firm's long term cost ratio $\bar{\gamma}$ is calculated based on the long term industry median. For each one digit SIC industry we calculate a growing window median costs ratio beginning in 1970 and up to 2009. Valuing firm i at time t , we use firm i 's industry's long term median cost ratio until time $t-1$ as the expected long term costs. As costs directly determine a firm's profit both the initial and the long term cost parameters are crucial and strongly affect the results. The initial volatility of costs ϕ_0 is obtained by running firm specific AR(1) regressions on the cost ratios and calculating the standard deviation of the residuals, while long term volatility of variable costs $\bar{\phi}$ is determined as a growing window industry median cost ratio on a three digit SIC code level starting 1970. Finally, we assign the industry specific medians of the estimated standard deviations to the individual firms. This is consistent with assuming similar developments within industries.

In the following we present the uncritical parameters, meaning that they do not affect estimated firm value results largely.

4.2.3. *Implementing balance sheet and the remaining income statement items*

Recall that the input parameters for the balance sheet and the remaining income statement items, such as depreciation, are given in equation (8), (9) and (11). Initial property, plant and equipment

$PPE(0)$ is calculated as Compustat items for net property plant and equipment plus other assets. Due to acquisition activity and other expansion related investments capital expenditures and depreciation ratios are extremely noisy for growing firms. The use of a constant investment and depreciation rate based on historical accounting information might therefore lead to biased results. To overcome biases of expansion related one time effects we model firm i 's constant rates of investment cr and depreciation dp as the long term industry median. For firm i 's cash and cash equivalents X at time t we calculate the sum of Compustat items for cash, total receivable minus accounts payable, other current assets and treasury stock.

4.2.4. *Implementing environmental and risk parameters*

In line with Schwartz and Moon (2000, 2001) and given the long term interest rate from the Federal Reserve we use for simplicity the risk free rate of 5.5% p.a. which translates to 1.35% per quarter. However, as shown by an intensive sensitivity analysis in the robustness section it does not drive the results. Corporate tax rates are 35% as in Bradshaw (2004). The risk premium for each of the stochastic processes λ_i ($i = R, \mu, \gamma$) is calculated as:

$$\rho_{r_M, i} \cdot \sigma_{r_M} = \frac{\text{Cov}(r_M, i)}{\sigma_i} \quad (15)$$

where r_M is the return of the Nasdaq Composite Index over the preceding seven quarters and σ_{r_m} is the Nasdaq Composite Index standard deviation.

4.2.5. *Implementing simulation parameters*

For each valuation, we use 10,000 simulations with steps of one quarter and up to 25 years. At the end of the simulation horizon, the enterprise value is given by the time $t=100$ cash value plus the residual value EBITDA multiplied with 10 in line with Schwartz and Moon (2001). A firm

fails at any given time $t=s$, where $s \in [1;100]$, within the simulation horizon when the available cash falls below zero. The liquidation value then is given as:

$$\widehat{EV}_{SM_s}^{luq} = \begin{cases} PPE_s + X_s, & \text{if } -X_s < PPE_s \\ 0, & \text{else} \end{cases} \quad (16)$$

where PPE_s is the amount of property, plant and equipment at default plus the negative cash X_s available. The Schwartz-Moon model estimated enterprise value is calculated by averaging all 10,000 simulated enterprise values and discounting the average value to time $t=0$.

4.3. Summary statistics

Table 2 reports summary statistics for our sample.

-----Please insert Table 2 approximately here-----

Panel A, Table 2, shows industry distribution primarily based on the SIC code classification by Bhorjraj and Lee (2002). The largest group is computer firms, accounting for 40% of our sample. Other major industries are electronics (31%), biotechnology (18%) and telecommunications (11%). Panel B, Table 2, reports financial statement information. For convenience, we report flow items as annualized values calculated as the sum over four quarters. On average, firms report annual revenues of \$1.8 billion. A median value of \$142 million shows the existence of extreme upscale outliers and the small firm structure of our sample. Median cash and cash equivalents holdings is \$72 million, while we also find some firms with negative cash holdings. This is the case for firms where the accounts payable exceeds the sum of cash, treasury stock and receivables, but this only occurs in 1% of the observations. Median total assets are \$170 million. The

large asset variation, with the smallest firm reporting total assets of less than \$1 million and the largest firm with assets above \$280 billion, shows significant heterogeneity within the sample. Median leverage, calculated as interest bearing debt scaled by total assets is 7%. As expected, we find debt financing to be only a minor security choice for technology growth firms. Within 34% of all observations, the underlying firm reported negative earnings and therefore profitability oriented multiples, such as Price-Earnings, cannot be considered. Median annual earnings are 4 \$m, while we also face extreme upside and downside outliers. Even taking EBIT into account as a profitability measure, 28% of all firm quarter observations report negative profits. Panel C, Table 2, reports summary statistics for the seven critical parameters used within the Schwartz-Moon approach. On average, firms exhibit mean annual sales growth rates of 29% over the preceding 7 quarters while we also face several annual growth rates of more than 1,000% percent. The mean initial cost ratio, calculated as total costs scaled by sales, is 91% while maximum values are up to 150%. This indicates the growth firm's potential to reduce costs over time to increase profitability in the long run. The long term cost ratio is calculated using a growing window approach based on three digit SIC industry classifications to capture industry specific characteristics. While being on comparable median levels to initial costs, this approach assures less volatile long term cost structures indicated by the significantly reduced inter quartile range. The long term annual revenues growth is exogenously set to a 3% inflation rate. The initial volatility of revenues growth rate has a median of 5% while the corresponding measure for the initial volatility of variable cost ratio is 8%. The latter also has a higher variability pictured by an inter-quartile range of twice the growth rate's initial volatility. Finally, the speed of convergence has a median of 0.17 corresponding to a half-life for the stochastic processes of 4.1 quarters. Panel D, Table 2, reports market values. Market capitalization is considered four months following the

date the underlying financial statement refers to. This way we verify that financial statement information was available to market participants by the time we analyze market values.⁷ Overall, the median enterprise value in our sample is \$321 million calculated as the sum of market capitalization provided by CRSP plus long term debt and debt in current liabilities.

5. Results

Prior studies generally report valuation accuracy based on logarithmic errors as in Kaplan and Ruback (1995) or percentage errors such as Francis, Olsson and Oswald (2000). For comparison, we report both error measures in Table 3 to shed light on our research question regarding overall valuation accuracy. Absolute log errors are defined as the ratio of the estimated value to the market value, $abs \log error = abs(\ln(\widehat{EV}/EV))$. Absolute percentage error is the absolute difference between actual and model predicted price, scaled by the actual price, $abs \text{ rel error} = abs((\widehat{EV} - EV)/EV)$. Panel A, Table 3, reports absolute log errors for the 29,477 firm quarter observations. Column one reports the error accuracy of the Enterprise-Value-Sales multiple controlling for industry and return on assets as in Alford (1992). Over the whole time period, the relative valuation approach yields median estimation errors of 59%, which is in line with Liu, Nissim and Thomas (2002). The mean of 75% shows the existence of upscale outliers. The fraction of companies which inhibit valuation errors larger than one is 27%. Column two reports results for the Schwartz-Moon model. In terms of absolute log valuation errors, this approach yields slightly higher errors with a median of 63%. The difference is significant on a 1% level due to the large sample size. The interquartile range, as the primary measure of dispersion, shows

⁷ Additionally, we considered market capitalization two and three-months following the date the financial statements refers as well as mean values over six months following this date. Overall, our results are not influenced by this decision.

a slightly looser fit than for the Enterprise-Value-Sales Multiple and the fraction of valuation errors larger than one is slightly higher as well.

Panel B, Table 3, reports results for absolute percentage errors. In line with absolute log error results, the EV-Sales-Multiple yields a small but still significantly higher accuracy than the fundamental Schwartz-Moon model (2 median percentage points). In this case, however, the Schwartz-Moon model represents the tighter fit considering the IQ-range. Mean and standard deviation are influenced by outliers and therefore are rather high.

-----Please insert Table 3 approximately here-----

Figure 3 complements the absolute valuation errors from Table 3 graphically by showing logarithmic and relative error distributions for both valuation approaches, i.e., the Schwartz-Moon model and EV-Sales-Multiple. Panel A, Figure 3, shows the kernel density plot of the logarithmic errors. While none of the approaches has a bias in terms of log errors, the EV-Sales multiple provides the more accurate valuations resulting in a tighter error distribution. Panel B, Figure 3, shows the results for relative valuation errors. Here, the Schwartz-Moon model has a higher density below zero indicating a higher fraction of undervaluation (55% vs. 48%) and a fatter tailed distribution.

-----Please insert Figure 3 approximately here-----

In sum, we conclude that -on average over the time period from 1992 to 2009- the Schwartz-Moon model is nearly as accurate as the EV-Sales-Multiple with respect to deviations from observed market values.

Looking closer at these results, Table 4 reports median absolute log valuation errors for several industries and different firm sizes. Panel A, Table 4, reports results for different industries aggregated into two digit SIC codes.

-----Please insert Table 4 approximately here-----

Although we find only a slight overall performance difference for the Schwartz-Moon model and the Enterprise-Value-Sales-Multiple, these two approaches differ considerably among industries. Looking at the absolute log errors on two digit SIC levels we see that Schwartz-Moon results in lower median valuation errors for pharmaceutical firms under SIC code 28 and computer companies (SIC codes 35, 73). On the other hand, the multiple valuation approach performs clearly better for telecommunication firms (SIC code 48) and biological research companies (SIC code 87) with respect to deviation from observed values. One reason might be that given our implementation the estimated speed of convergence coefficients for these two industries are on the lower end of the range corresponding to long half-lives of around 10 quarters for the competitive advantages. Furthermore, the structure of the industries might play a role as, e.g., telecommunication firms have a high proportion of large-sized firms. Without these two industries the Schwartz-Moon model would on average perform slightly better than the EV-Sales-Multiple with an overall median log error of 0.56 compared to 0.59. Panel B, Table 4, reports valuation errors for different firm sizes. As a measure of firm size we use total assets. As expected, both

valuation approaches yield the largest errors for those 25% of observations where firms reported total assets below 50 \$m. Still, the Schwartz-Moon model produces smaller deviations. By contrast, the relative valuation approach performs considerably better the larger the underlying firms become resulting in clear outperformance for the last quartile.

Turning to the final research question, we examine whether the Schwartz-Moon model can differentiate and detect periods of market over- and undervaluation. Therefore, we divide the sample time span from 1992 to 2009 into three market periods: From the beginning of the time span to around 1998 as the period before the dot com bubble. This is followed by the time of the dot com speculation bubble, its burst and the recovery until 2007. Finally, the time until 2009 covers the recent financial crisis. Figure 4 shows the median absolute errors and median errors on a quarterly basis spanning 1992 until 2009 for the two valuation approaches. Panels A and B of Figure 4 report absolute log and relative errors and show the immense volatility of model accuracy. Panels C and D of Figure 4 report the non-absolute log and relative errors in order to detect market mispricing from a fundamental perspective. Positive (negative) errors thereby result from higher (lower) predicted than observed values, hence representing market undervaluation (overvaluation). As already argued the multiple approach is driven by market sentiment and therefore cannot distinguish between the three periods. Hence, the multiple's errors remain fairly stable around zero as in Liu, Nissim and Thomas (2002). During the first period the absolute valuation errors generated by the Schwartz-Moon model (red curve) in the beginning of the 1990ties are highest while the multiple yields quite small deviations. The non-absolute valuation errors from Schwartz-Moon indicate a undervaluation of the growing technology market, which is declining until around 1998. The second period is characterized by an increase of absolute errors for both valuation methods with a peak in 2000 around the burst of the speculative bubble which is prob-

ably based on the extreme high valuations already reported in Ofek and Richardson (2003). Thereafter the valuation errors decrease again. Noteworthy the Schwartz-Moon model results in higher accuracy during this time, which might be caused by its explicit consideration of default risk. Moreover, the Schwartz-Moon model correctly pictures the general overvaluation of the technology sector during that time which can be seen in Panel C and D of Figure 4. Interestingly, this period of overvaluation lasts until 2007. Entering the third period at the beginning of the financial crisis in 2007 the picture changes again: the Schwartz-Moon model now indicates an undervaluation of the technology sector. The reason might be a market-overreaction from a fundamental perspective resulting in the undervaluation of firms during the peak of the financial crisis 2008/09. Around the beginning of 2009 – simultaneously to a 6-year low of the Nasdaq Composite Index - the Schwartz-Moon valuation errors result in a clear spike. From the accuracy perspective of Panel A and B, Figure 4, the spike results in lower accuracy of the Schwartz-Moon model. In general, a method like the EV-Sales-Multiple, which captures the market mood, produces smaller inaccuracy but does not have the ability to indicate over- or undervaluation

-----Please insert Figure 4 approximately here-----

Finally, to assess whether the Schwartz-Moon model provides reasonable default probabilities, we extend the market mispricing results by analyzing the generated bankruptcy figures over time.

-----Please insert Table 5 approximately here-----

Recall that one of the main advantages of the Schwartz-Moon model compared to the sales-multiple approach is that it produces estimates for the probability of default for a 25-year period. Table 5 reports summary statistics on the model implied default rates. The median default rate for our sample is 29% while for less than 2% of the observations there were no defaults during the 10,000 simulations. These are reasonable levels as, e.g., Cumming and MacIntosh (2003) report failure rates up to 30% for venture capital investors' portfolios mainly consisting of technology firms.

-----Please insert Figure 5 approximately here-----

Figure 5 shows the evolvement of the median predicted number of defaults over time. There is a clear upward trend from the mid 90ies until 2000 reflecting the increased business activity. During the burst of the dot-com bubble in 2000 the Schwartz-Moon model predicts median default rates of up to 40%. This high level remains until the beginning of 2009 with another peak in 2008, whereafter it drops to levels around 25% again. Compared to the market credit spread of Baa rated corporate bonds to US treasury bills, the Schwartz-Moon model seems to be reacting to fundamental credit risk changes before the market does. This can also be seen at the dot-com bubble around 2000. Interestingly, the model predicted default probabilities remain high from 2003 on whereas the market implied credit risk is declining until 2007.

In sum, we conclude that the Schwartz-Moon model shows the ability to illustrate market over- and undervaluation, while we suggest that the credit risk aspects of Schwartz-Moon would be worthwhile to explore in future research.

6. Robustness checks

Given that the Schwartz-Moon model needs many input parameter estimates of which we identified seven as critical, this section provides robustness tests. Thus, Table 6 summarizes the results for the sensitivity analysis for the seven critical parameters. Varying the input parameters for a range of $\pm 10\%$ we see that the median absolute errors remain fairly stable except for the long term cost ratio. Looking more closely at the default rates the driving parameters are identified as initial and long term cost ratios as well as the speed of adjustment. The high impact of the long term cost ratio is reasonable because a 10% change in an average long term cost ratio of 0.9 is rather high, resulting, e.g., in a decoupling of the long term profit margin from 0.01 to 0.1. Varying the terminal value multiple from 10 to 9 and 11 has no large impact as the multiple is applied only after a time horizon of 25 years. Generally, in contrast to the absolute valuation errors the estimates for the probability of default react more sensitive to a change in input parameters because the threshold for the cash level stays exogenously at zero.

-----Please insert Table 6 approximately here-----

Additionally, we recalculate the results based on the Global Industry Classification Standard (GICS) instead of the SIC classification with the definition of high technology firms provided by Kile and Phillips (2009). They argue that GICS provide higher accuracy to identify high technology firms than SIC codes and hence should be preferred. However, our results (unreported, but available upon request) remain qualitatively the same.

Finally, as argued above, our results are interpreted in two ways. The first view is a market mispricing perspective and focuses on the time dimension, meaning that the model price is

correct and the market might be wrong. The second perspective averages the results over the complete time span from 1992 until 2009 and compares model predicted prices to real market prices. Here, deviations of model predicted prices from market prices are regarded as inaccuracy, meaning that the market price can be -one average- used as a correct benchmark and thus incorporate the notion of market efficiency. With the second view in mind, we predict, that -on average- the Schwartz-Moon model prices should be positively correlated with observed market prices. In order to test this prediction as a further robustness test, Table 7 reports regression results, where the observed market value is regressed on the predicted value to determine the model's explanatory power. We should expect a positive and significant coefficient, however, different from Francis, Olsson and Oswald (2000), it does not have to be close to one as Schwartz-Moon estimates the firm's fundamental value independently from market sentiment. The regression results fulfill these expectations with the estimated coefficients being positive and significant.⁸

-----Please insert Table 7 approximately here-----

7. Discussion and conclusion

The valuation of innovative growth firms is a challenging task as these firms deviate from basic assumptions such as positive earnings, sufficient size and analyst coverage mandatory to most common valuation procedures. To value this type of firm Schwartz and Moon (2000, 2001) develop a valuation methodology in which firm value arises under the development of primarily three stochastic processes for revenues, growth and costs. Although this model has several theoretical advantages over common valuation approaches, its accuracy had yet to be tested on a

⁸ We also re-estimated all specifications employing linear feasible general least squares estimators and results (unreported, but available up on request) are qualitatively the same.

large sample of firms. Based on economic theory this paper implements the Schwartz-Moon model only relying on externally available historical accounting information and benchmarks this implementation against a common multiple valuation approach on around 30,000 technology firm quarter observations.

Given the 22 input parameters of the Schwartz-Moon model it is clear that there are many ways to implement the model. Changing the estimation of the input parameters naturally changes the results. However, we think our implementation based on economic and management theory is reasonable and intuitive. Moreover, in the robustness section we show that varying the input parameters at a range of ten percent does not change the results qualitatively. Hence, this paper is a plausible first step to extent this line of research.

Our results are the following: Primarily, we find that overall the Schwartz-Moon model performs nearly as good as the Enterprise-Value-Sales Multiple concerning accuracy in our implementation. On industry levels, however, there are major differences with pharmaceutical and computer firms having significantly lower valuation errors for the Schwartz-Moon model. Additionally, it is more accurate for smaller firms measured by total assets. Second, the Schwartz-Moon model shows the ability to indicate severe mispricing by the market as it both pictures the overvaluation during the dot-com bubble and the undervaluation during the 2008 financial crisis due to the overreaction by the markets. Finally, it also represents well the increased frequency of defaults around the dot-com bubble. Consequently, the performance of the Schwartz-Moon approach as a credit risk model should be explored in future research.

Given the theoretical advantages, the empirical results and its fundamental perspective, we conclude that the Schwartz-Moon model for once can be seen as supplement that can help to establish more precise value estimates for growth firms and provide an indication of their default

probability. Considering the accuracy it is especially suitable for smaller firms and firms from the pharmaceutical and computer industries.

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Appendix 1

Variable Definitions

No.	Label	Description	Measurement (abbreviations are Compustat mnemonics)
<i>critical parameters</i>			
1	μ_0	= initial growth rate of revenues	$= \frac{1}{7} \sum_{t=0}^{-6} \ln(\text{saleq}_t / \text{saleq}_{t-1})$
2	η_0	= initial volatility of the sales growth rate	$= \sqrt{\frac{1}{n-1} \sum_{j=0}^t (\widehat{\varepsilon}_{t-j} - \bar{\varepsilon})^2}$, where $\widehat{\varepsilon}_j$ are the estimated residuals of the AR(1) process: $\mu_t = \alpha + \beta\mu_{t-1} + \varepsilon_t$
3	φ_0	= initial volatility of variable costs	$= \sqrt{\frac{1}{n-1} \sum_{j=0}^t (\widehat{\varepsilon}_{t-j} - \bar{\varepsilon})^2}$, where $\widehat{\varepsilon}_j$ are the estimated residuals of an AR(1) process on the cost rate $c = (\text{cogsq} + \text{xsgaq}) / \text{saleq}$: $c_t = \alpha + \beta c_{t-1} + \varepsilon_t$
4	γ_0	= initial variable cost	$= \frac{1}{8} \sum_{t=0}^{-7} \frac{\text{cogsq}_t + \text{xsgaq}_t}{\text{saleq}_t}$
5	$\bar{\mu}$	= long term sales growth rate	= 0.0075
6	$\bar{\gamma}$	= industry median long term variable cost	$= \text{median}_{sic3} \sum_{t=1970}^T \frac{\text{cogs}_t + \text{xsga}_t}{\text{sale}_t}$, for $T = 1992, \dots, 2009$
7	κ	= speed of adjustment	$= \text{median}_{sic2} \left(-\frac{1}{4} \ln \left(\sum_{t=5}^{t-8} \frac{\text{saleq}_t - \text{saleq}_{t-1}}{\text{saleq}_{t-1}} / \sum_{t=1}^{t-4} \frac{\text{saleq}_t - \text{saleq}_{t-1}}{\text{saleq}_{t-1}} \right) \right)$
<i>uncritical parameters</i>			
8	R	= revenues	= saleq
9	X	= cash and cash equivalents	= cheq + rectq + acoq + tstkq - apq
10	L	= loss carry forward	= tlcf
11	P	= property, plant and equipment	= ppent + aoq
12	σ_0	= initial sales volatility	$= \sqrt{\frac{1}{7} \sum_{t=0}^{-7} \left(\frac{\text{saleq}_t - \text{saleq}_{t-1}}{\text{saleq}_{t-1}} - \mu_0 \right)^2}$
13	$\bar{\sigma}$	= long term volatility	= 0.05
14	$\bar{\varphi}$	= industry median long term volatility of variable costs	$= \text{median}_{sic3} \left(\text{std}_{t=1970}^T \left(\frac{\text{cogs}_t + \text{xsga}_t}{\text{sale}_t} \right) \right)$, for $T = 1992, \dots, 2009$
15	F	= fix costs	= 0
16	cr	= industry median capital expenditure rate	$= \text{median}_{sic3} \sum_{t=1970}^T \left(\frac{\text{capx}_t}{\text{sale}_t} \right)$, for $T = 1992, \dots, 2009$
17	dp	= industry median depreciation rate	$= \text{median}_{sic3} \sum_{t=1970}^T \left(\frac{dp_t}{\text{ppent}_t + \text{ao}_t} \right)$, for $T = 1992, \dots, 2009$

(continued on next page)

(Variable Definitions continued)

No.	Label	Description	Measurement
18	τ	= tax rate	= 0.35
19	r_f	= risk free rate	= $\sqrt[4]{(1 + 0.055)} - 1 = 0.0135$
20	λ_R	= risk premium sales	= $\rho_{r_M, sales} \cdot \sigma_{r_M} = \frac{Cov(r_M, sales)}{\sigma_{sales}}$
21	λ_μ	= risk premium sales growth	= $\rho_{r_M, \mu} \cdot \sigma_{r_M} = \frac{Cov(r_M, \mu)}{\sigma_\mu}$
22	λ_γ	= risk premium variable costs	= $\rho_{r_M, \gamma} \cdot \sigma_{r_M} = \frac{Cov(r_M, \gamma)}{\sigma_\gamma}$
	M	= terminal value multiple	= 10
	EV_t	= company (entity) value	= $price \cdot shrout + dl ttq + dlcq$
	$RNOA_t$	= return on net operating assets	= $\frac{\sum_{t=1}^{-4} EBITQ_t}{ppentq + actq - lctq}$

Data Sources

COMPUSTAT					
Quarterly data (q)			Annual data (a)		
item number	mne- monic	description	item number	mne- monic	description
#1	xsgaq	Selling, General, and Administrative Expenses	#8	ppent	PP&E (Net) – Total
#2	saleq	Sales (Net)	#12	sale	Sales (Net)
#5	dpq	Depreciation and Amortization	#14	dp	Depreciation and Amortization
#21	oibdpq	Operating Income Before Depreciation (EBITDA)	#41	cogs	Cost of Goods Sold
#30	cogsq	Cost of Goods Sold	#52	tlcf	Tax Loss Carry Forward
#36	cheq	Cash and Equivalents	#69	ao	Assets – Other
#37	rectq	Receivables - Total	#128	capx	Capital Expenditures
#39	acoq	Current Assets - Other	#189	xsga	Selling, General, and Administrative Expenses
#40	actq	Current Assets - Total			
#42	ppentq	PP&E (Net) - Total			
#43	aoq	Assets - Other			
#44	atq	Assets - Total			
#45	dlcq	Debt in Current Liabilities			
#46	apq	Accounts Payable			
#49	lctq	Current Liabilities - Total			
#51	dlttq	Long-Term Debt - Total			
#54	ltq	Liabilities - Total			
#58	req	Retained Earnings - Quarterly			
#59	ceqq	Common Equity - Total			
#69	niq	Net Income (Loss)			
#98	tstkq	Treasury Stock - Dollar Amount - Total			
CRSP					
Monthly data					
n.a.	price	stock price (adjusted for stock splits etc.)			
n.a.	shrout	shares outstanding (adjusted for stock splits etc.)			

Table 1: Sample selection procedure

	Description	Time Period	Observations (Firm Quarters)	No. of firms (Compustat identifier: GVKEY)
1	Firm-quarter observations on the intersection of COMPUSTAT and CRSP	1961Q1-2009Q4	940,513	22,904
2	drop observations with changing fiscal years or duplicates in terms of NPERMNO (unique identifier from the CRSP database) and date or GVKEY (unique identifier from the COMPUSTAT database) and date	1961Q1-2009Q4	-13,726 =926,787	22,904
3	drop observations with missing market data from CRSP	1961Q4-2009Q4	-20,100 =906,687	22,894
4	drop observations that are not within the extended Bhojraj/Lee (2002) SIC code definition	1961Q4-2009Q4	-751,686 =155,001	5,276
5	drop observations, where relevant items* are negative	1971Q1-2009Q4	- 63,223 =91,778	3,779
6	keep data within time span	1992Q1-2009Q4	-19,410 =72,368	3,363
7	drop observations with missing data for the Schwartz-Moon input parameter	1992Q1-2009Q4	-42,891 =29,477	2,262

This table shows the sample selection procedure. We use the quarterly CRSP/Compustat merged database in order to obtain our sample. Thus, all accounting items are from the quarterly Compustat database, with few exceptions such as loss carry forwards which are only available on a yearly basis. These yearly data items are obtained from the Compustat Annual data files. All market data, i.e., prices and shares outstanding, were obtained from the monthly CRSP database. Market data from CRSP is used four month after the fiscal year quarter for each company to ensure, that market prices incorporate the last available accounting information. We use the high technology industry SIC code definition of Bhojraj and Lee (2002) in this study. That is biotechnology SIC codes (2833-2836 and 8731-8734), computer SIC Codes (3570-3577 and 7371-7379), electronics (3600-3674) and telecommunication (4810-4841) extended in this paper by SIC code 7370. The considered time span ranges from Q1 1992 to Q4 2009.

* These items are: acoq aoq apq capxy cheq cogsq tlcf dlcq dltdq dpq ppentq rectq saleq tstkq xsgaq.

Table 2: Summary statistics

<i>Panel A: Industry Distribution</i>	Biotechnology		Computers		Electronics		Telecom		Total
# obs.	5,282		11,813		9,217		3,165		29,477
%	18%		40%		31%		11%		100%
<i>Panel B: Financial statement information</i>	Mean	Median	q25%	q75%	IQ-Range	Min	Max	% negative obs.	
Revenues	1,822.15	141.98	46.10	566.37	520.27	0.05	125,760.56	0%	
Cash and Cash Equivalents	792.87	71.76	18.36	278.37	260.00	-2,202.75	120,248.00	1%	
Total Assets	2,696.26	169.74	49.91	831.83	781.92	0.68	284,528.00	0%	
Leverage	17%	7%	0%	25%	25%	0%	2764%	0%	
Earnings	133.46	3.83	-3.46	32.86	36.32	-56,329.70	19,337.00	34%	
EBIT	261.08	8.28	-0.71	62.49	63.20	-5,378.40	23,910.00	28%	
<i>Panel C: Key ratios</i>	Mean	Median	q25%	q75%	IQ-Range	Min	Max		
Annual Sales Growth	29%	19%	9%	36%	27%	0%	1373%	-	
Initial Variable Cost Ratio	91%	88%	79%	96%	17%	62%	150%	-	
Long Term Variable Cost Ratio	91%	91%	88%	95%	6%	85%	98%	-	
Long Term Annual Revenue Growth	3%	3%	3%	3%	0%	3%	3%	-	
Initial Volatility of Revenues Growth Rate	7%	5%	3%	9%	6%	1%	22%	-	
Initial Volatility of Variable Cost Ratio	17%	8%	4%	17%	13%	2%	93%	-	
Speed of Convergence	0.17	0.16	0.14	0.19	0.06	0.08	0.31	-	
<i>Panel D: Market values</i>	Mean	Median	q25%	q75%	IQ-Range	Min	Max		
Market Capitalization	3,991.63	267.82	67.79	1,147.09	1,079.31	0.26	505,037.44	-	
Enterprise Value	4,606.48	320.69	80.89	1,445.86	1,364.97	0.28	505,037.44	-	

(continued on next page)

(Table 2 continued)

This table reports summary statistics for a sample of 29,477 technology firm quarter observations. Panel A reports the sample's industry distribution according to Bhojraj and Lee (2002) with SIC codes in parentheses: biotechnology (2833-2836 and 8731-8734), computers (3570-3577 and 7370-7379), electronics (3600-3674) and telecommunications (4810-4841). Note that we add SIC code 7370 to their sample definition. Panel B reports financial statement information. All financial statement items are on a quarterly basis (q) unless stated otherwise as annual items (a) in appendix 1. Note that quarterly flow figures are aggregated to meaningful yearly figures. Thus, each observation contains the sum of the last four quarter values. COMPUSTAT item mnemonics are given in parenthesis. All values are given in million \$ except of percentages denoted as %. Revenues are given by sales (saleq). Cash and cash equivalents is calculated as the sum of cash (cheq), receivables total (rectq), current assets other (acoq) and treasury stocks (tstkq) minus accounts payable (apq). Total assets is the balance sheet total (atq). Leverage is calculated as interest bearing debt, which is the sum of debt in current liabilities (dlcq) and long term debt (dlttq), divided by total assets (atq). Earnings are defined as net income/loss (niq) and EBIT is operating income (oibdpq) after depreciation (dpq). Panel C reports key ratios. Annual sales growth is the annualized growth rate of the current quarter. The initial variable cost ratio is measured by the mean of the ratio of costs of goods sold (cogsq) plus selling, general, and administrative expenses (xsgaq) divided by sales (saleq). Long term variable cost ratio is calculated using a growing window approach based on three digit SIC code industry classification beginning in 1970 and until the most recent quarter. The long term annual growth rate of revenues is set to 3%. The initial volatility of revenue growth rates is determined from the standard deviation of the residuals from an AR(1) regression of the growth rates. Analogously, the initial volatility of the variable cost ratio is determined from the AR(1) regression residuals of the cost ratios. The speed of convergence parameters result from the convergence of the previous eight quarterly sales data points as presented in appendix 1. Panel D reports market data. Market capitalization is calculated from CRSP as price times shares outstanding. Enterprise value is the sum of market capitalization, long term debt (dlttq) and debt in current liabilities (dlcq).

Table 3: Valuation errors

Valuation Errors			
Panel A	Absolute Log Errors		
	EV-Sales	Schwartz-Moon	delta
Median	0.59	0.63	-0.04***
IQ-Range	0.78	0.81	
90%-10%	1.48	1.53	
95%-5%	1.92	1.96	
Mean	0.75	0.78	
Standard deviation	0.64	0.67	
>100%	0.27	0.29	
Panel B	Absolute Percentage Errors		
Median	0.54	0.56	-0.02***
IQ-Range	0.66	0.57	
90%-10%	2.31	1.75	
95%-5%	3.94	3.06	
Mean	1.16	1.40	
Standard deviation	4.74	27.78	
>100%	0.23	0.18	
N	29,477	29,477	

This table reports the distribution of valuation errors for various prediction measures. Panel A reports absolute log errors, defined as the absolute logarithm of the ratio of the estimated value to the market value. Panel B reports absolute percentage errors. Absolute percentage error is the absolute difference between actual and model predicted price, scaled by the actual price. The table values represent the median, the inter-quartile range (IQ-Range), 90th-percentile minus 10th-percentile (90%-10%), the 95th-percentile minus 5th-percentile (95%-15%), the mean, standard deviation and the percentage of valuation errors larger than 100% (>100%). The delta column represents the difference which is tested for significance with the Wilcoxon sign rank test. One/ two/ three asterisks represent significance at the 10%/ 5% / 1% level.

Table 4: Valuation errors by industry classification and firm size

Median Absolute Log Errors					
Panel A: by 2 digit SIC codes					
	Industry	EV-Sales	Schwartz-Moon	delta	# obs.
28	pharmaceutical	0.62	0.52	0.11***	3,799
35	computer (hardware)	0.65	0.53	0.11***	3,272
36	electronics	0.56	0.57	-0.01*	9,217
48	telecommunication	0.47	1.00	-0.53***	3,165
73	computer (software)	0.61	0.59	0.02***	8,541
87	biological research	0.70	1.49	-0.80***	1,483
Total		0.59	0.63	-0.04***	29,477
Panel B: by firm size classification					
0 - 25%		0.72	0.70	0.03**	7,370
26% - 50%		0.62	0.61	0.01*	7,369
51% - 75 %		0.54	0.56	-0.02*	7,369
76% - 100%		0.50	0.64	-0.15***	7,369
Total		0.59	0.63	-0.04***	29,477

This table reports the distribution of median log valuation errors, defined as the absolute logarithm of the ratio of the estimated value to the market value for firms. Panel A reports absolute log errors for firms according to their two digit SIC code. Panel B reports absolute log errors by firm size quartile. Firm size is measured by total assets (Compustat item: atq). The delta column represents the difference which is tested for significance with the Wilcoxon sign rank test. One/ two/ three asterisks represent significance at the 10%/ 5% / 1% level.

Table 5: Model implied default probability

Default rates	
	Schwartz-Moon
Median	29%
Mean	35%
Standard deviation	29%
Zero default obs.	492
All default obs.	256

This table reports summary statistics of model implied default rates for 29,477 firm quarter observations. Column one reports results for the Schwartz-Moon model. Median, mean, and standard deviation values are obtained by the ratio between defaulted simulation paths and 10,000, the total number of simulations per firm quarter. Zero/All default obs. reports observations in which the respective model predicted no/complete failure in all simulation paths.

Table 6: Sensitivity Analysis

			Median	IQ-Range	Mean	Std Dev	Median	IQ-Range	Mean	Std Dev
0	baseline	abs log error	0.63	0.81	0.78	0.67	0.63	0.81	0.78	0.67
		abs rel error	0.56	0.57	1.40	27.78	0.56	0.57	1.40	27.78
		prob of def	0.29	0.42	0.35	0.29	0.29	0.42	0.35	0.29
+10%							-10%			
I	initial growth rate of revenues	abs log error	0.63	0.82	0.78	0.67	0.63	0.82	0.78	0.67
		abs rel error	0.56	0.58	1.52	34.43	0.56	0.56	1.30	22.59
		prob of def	0.30	0.44	0.35	0.29	0.29	0.43	0.34	0.29
II	volatility of revenues growth rate	abs log error	0.63	0.81	0.78	0.67	0.63	0.81	0.78	0.67
		abs rel error	0.56	0.57	1.39	27.56	0.56	0.57	1.41	28.05
		prob of def	0.29	0.44	0.35	0.29	0.30	0.44	0.35	0.29
III	initial variable cost	abs log error	0.62	0.82	0.79	0.69	0.63	0.82	0.79	0.66
		abs rel error	0.54	0.53	1.23	25.40	0.57	0.61	1.57	29.13
		prob of def	0.36	0.49	0.40	0.30	0.24	0.40	0.31	0.28
IV	initial volatility of variable cost	abs log error	0.62	0.81	0.78	0.66	0.63	0.82	0.79	0.68
		abs rel error	0.55	0.57	1.40	27.07	0.56	0.57	1.40	27.92
		prob of def	0.30	0.44	0.35	0.29	0.29	0.44	0.35	0.29
V	long term revenue growth	abs log error	0.63	0.82	0.78	0.67	0.62	0.81	0.78	0.67
		abs rel error	0.56	0.58	1.45	29.13	0.55	0.56	1.35	26.52
		prob of def	0.30	0.44	0.35	0.29	0.29	0.44	0.35	0.29
VI	long term costs	abs log error	1.56	1.15	1.64	0.91	0.81	0.98	0.95	0.75
		abs rel error	0.80	0.25	0.91	7.61	0.89	2.21	3.37	56.56
		prob of def	0.74	0.33	0.68	0.24	0.06	0.25	0.17	0.24

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(Table 6 continued)

VII	speed of convergence	abs log error	0.63	0.82	0.78	0.66	0.62	0.82	0.79	0.70
		abs rel error	0.56	0.56	1.03	7.32	0.56	0.59	3.66	191.67
		prob of def	0.27	0.45	0.33	0.29	0.32	0.43	0.37	0.28
VIII	interest rate	abs log error	0.62	0.81	0.78	0.67	0.63	0.82	0.79	0.67
		abs rel error	0.55	0.55	1.30	25.05	0.57	0.59	1.52	30.88
		prob of def	0.28	0.44	0.34	0.29	0.31	0.44	0.36	0.29
IX	terminal value multiple	abs log error	0.63	0.82	0.78	0.67	0.63	0.81	0.78	0.67
		abs rel error	0.56	0.58	1.45	28.72	0.55	0.56	1.35	26.85
		prob of def	0.29	0.44	0.35	0.29	0.29	0.44	0.35	0.29

This table reports summary statistics for the sensitivity of the absolute log error (abs log error), the absolute relative error (abs rel error) and the probability of default (prob of def) for a +/- 10% change of parameters. The table values represent the median, the inter-quartile range (IQ-Range), the mean and the standard deviation of the three measures. The first row gives the baseline case as means of comparison. In the nine following rows the corresponding input parameter is first increased by 10% to calculate the Schwartz-Moon results. The same procedure is then performed for a 10% decrease. All items such as initial growth rate of revenues are explained in appendix 1.

Table 7: Regression Analysis

Industry/Size		Type	Coeffi- cient	Constant	No. of obs.	Overall R ² (fixed effects)/ Adj. R ² (rank regression)	Prob. > F
Panel A							
28	pharmaceutical	Fixed Effects	0.12***	21.66***	3,799	0.18	0.00
		Rank Regression	0.90***	388.93***	3,799	0.83	0.00
35	computer (hardware)	Fixed Effects	0.13***	16.33***	3,272	0.38	0.00
		Rank Regression	0.93***	21.02***	3,272	0.86	0.00
36	electronics	Fixed Effects	0.19***	15.85***	9,217	0.45	0.00
		Rank Regression	0.96***	-1222.46**	9,217	0.84	0.00
48	telecommunica- tion	Fixed Effects	0.10***	39.01***	3,165	0.30	0.00
		Rank Regression	0.77***	6058.77***	3,165	0.74	0.00
73	computer (software)	Fixed Effects	0.08***	16.63***	8,541	0.16	0.00
		Rank Regression	0.92***	1800.03***	8,541	0.80	0.00
87	biological research	Fixed Effects	0.12***	19.67***	1,483	0.17	0.01
		Rank Regression	0.79***	6486.30***	1,483	0.66	0.00
	all	Fixed Effects	0.13***	20.02***	29,477	0.32	0.00
		Rank Regression	0.89***	1676.00***	29,477	0.79	0.00
Panel B							
0 - 25%		Fixed Effects	0.04***	6.40***	7,370	0.07	0.00
		Rank Regression	0.40***	2835.11***	7,370	0.15	0.00
26% - 50%		Fixed Effects	0.04***	13.40***	7,369	0.05	0.00
		Rank Regression	0.30***	7712.83***	7,369	0.09	0.00
51 - 75%		Fixed Effects	0.09***	23.14***	7,369	0.12	0.00
		Rank Regression	0.42***	10363.46***	7,369	0.20	0.00
76% - 100%		Fixed Effects	0.14***	39.12***	7,369	0.33	0.00
		Rank Regression	0.54***	11680.79***	7,369	0.34	0.00
	all	Fixed Effects	0.13***	20.02***	29,477	0.32	0.00
		Rank Regression	0.89***	1676.00***	29,477	0.79	0.00

This table reports the results of a fixed effects regression and a rank regression of observed firm value on predicted firm value including a constant. We choose the fixed effects specification after rejecting the random effects model based on a Hausman test ($p < 0.01$). In addition, the fixed effects model is also preferred to a pooled OLS estimate after performing an F-test on the firm fixed effects, which are significantly different from zero. The fixed effects regressions are performed on a per share basis and take time and firm cluster effects into account as in Petersen (2009). Adjusted R^2 is reported for the rank regression, while the overall R^2 shows model fit in case of the fixed effect estimates. The rank OLS regressions are performed on market values consistent with Iman and Conover (1979). Panel A presents regressions which are performed per two digit SIC industry classification. Panel B shows the results per size quartile, which is measured by total assets. One/ two/ three asterisks represent significance at a 10%/ 5%/ 1% level.

Figure 1: Income statement illustration

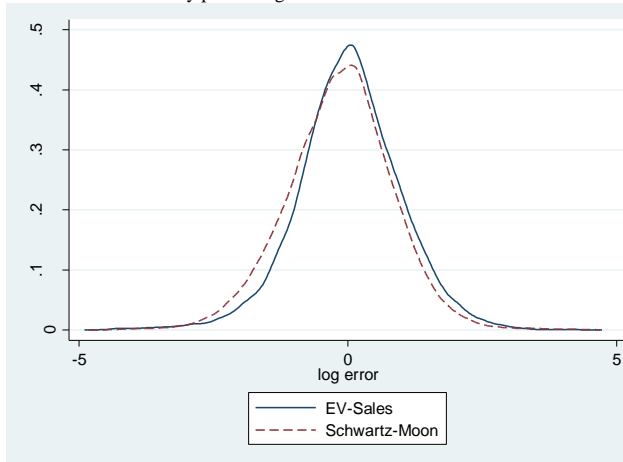
Income statement for time span ended at time t	
Revenues	(R)
- Costs	(C)
- Depreciation	(D)
- Tax	(tax)
= Net income	(Y)

Figure 2: Balance sheet illustration

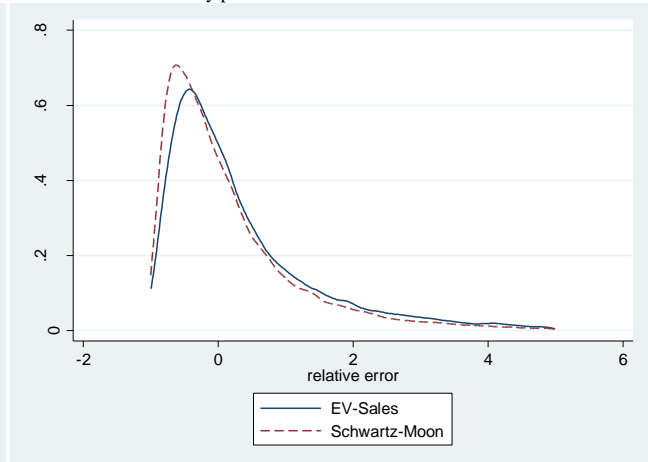
Balance Sheet at time t	
Property, Plant & Equipment (PPE)	Equity
Cash (X)	
	Debt
Assets	Liabilities

Figure 3: Valuation error distribution

Panel A: Kernel-density plot of log valuation errors



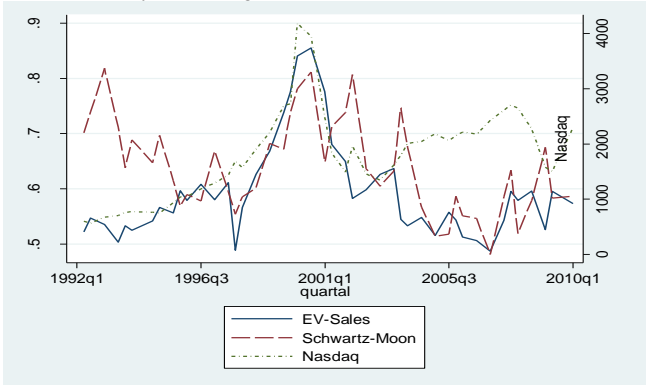
Panel B: Kernel-density plot of relative valuation errors



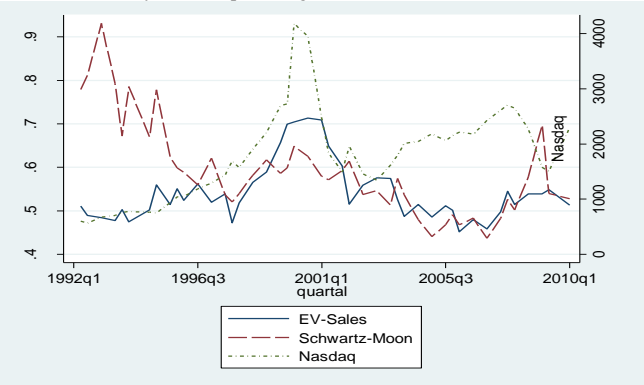
This figure shows a kernel density plot of valuation errors for the two different valuation approaches on a sample of 29,477 technology firm quarter observations. Panel A reports log valuation errors defined as the logarithm of the ratio of the estimated value to the market value. Panel B reports relative valuation errors which is the difference between actual and model predicted value, scaled by the actual value. The blue, solid line reports valuation errors for the Enterprise-Value-Sales-Multiple. The red, dashed line reports valuation errors for the Schwartz-Moon model.

Figure 4: Quarterly median valuation errors

Panel A: Quarterly absolute log errors



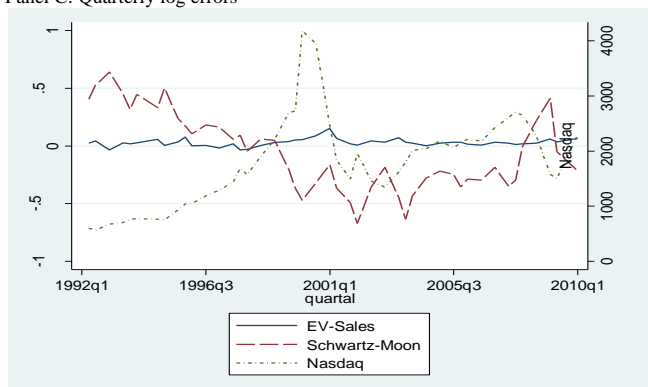
Panel B: Quarterly absolute percentage errors



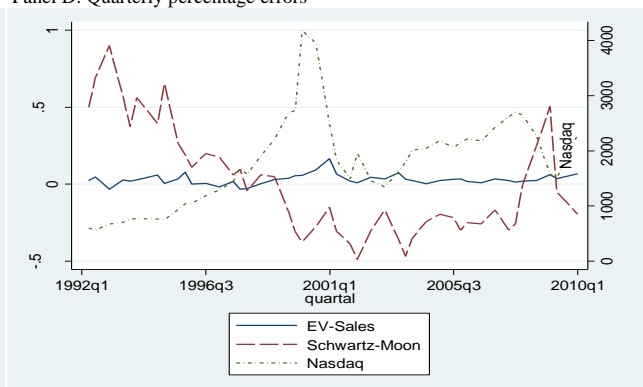
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(Figure 4 continued)

Panel C: Quarterly log errors

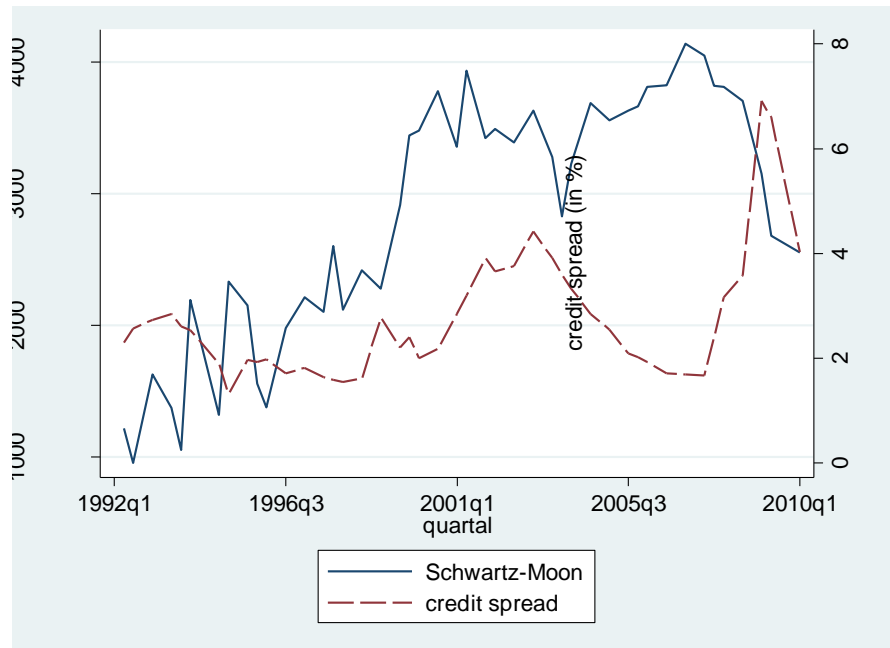


Panel D: Quarterly percentage errors



This figure shows quarterly median valuation errors spanning the time 1992 until 2009. Panel A reports median absolute log errors defined as the absolute logarithm of the ratio of the estimated value to the market value. Panel B reports median absolute relative valuation errors which is the absolute difference between actual and model predicted value, scaled by the actual value. Panel C and D report median log errors and percentage errors. The blue, solid line reports valuation errors for the Enterprise-Value-Sales-Multiple. The red, dashed line reports valuation errors for the Schwartz-Moon model. The green, dashed-dotted line reports the Nasdaq Composite as benchmark.

Figure 5: Median quarterly defaults



This figure shows quarterly median predicted defaults per 10,000 simulation runs spanning the time 1992 until 2009. The blue, solid line reports defaults predicted by the Schwartz-Moon model. The red, dashed line reports the credit spread between Moody's Seasoned Baa Corporate Bond Yield and U.S. 5-year treasury securities in percentage points as benchmark.